From Product to Dust: Looking at the Ways to Regenerate Value in Product Life Cycle

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FROM PRODUCT TO DUST: LOOKING AT THE WAYS TO REGENERATE VALUE IN PRODUCT LIFE CYCLE

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ABSTRACT

The shift from linear to circular patterns is on the way and rise many questions. In the last ten years, reuse and upcycling are gaining more attention. Since reduce and reuse were describe as a priority by the European Union, some leading projects are unveiled in different countries. Scale and quality of those projects push the reuse issue out of the shadow, far from original prejudices who associate waste and reuse to « poverty » and « Do It Yourself ». Although Reuse emerge as a prominent question, the idea and boundaries of « what is reuse » appears to be blur and not clearly understood. This situation lead to general incomprehension, even for professionals. Reuse, repurpose, upcycling and recycling are usually considered to wear the same meaning despite a huge difference on what it implies.
In this paper we will examine these different notions through a pedagogical case study. We will draw the different ways to regenerate value at all steps of product life cycle in a precise manner. This allows to better insight the meaning of those issues in the case of student design education. In the same time, it aims to be a tool for teaching sustainable design and waste management.

Keywords: Education, Circular economy, Ecodesign, Reuse, Upcycling

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1 INTRODUCTION

Speaking globally, about 10 billion tons of engineering materials per year are consumed. Steel reaches a consumption of ~ 0.8 billion tons per year followed by aluminum with 10 million tons per year. Commodity polymers reach high level consumption close to that of steel (Ghenai, 2012). Materials selection is not about choosing a material, but more about defining a profile of properties that best meets the needs of the design (Ashby *et al*., 2007, and Alonso *et al*., 2007). Among those properties, environmental profiles of materials are now of primary importance. Tools and methods have been developed to evaluate the eco-impact of material selection. A spectrum of levels of analysis exist, ranging from a simple eco-screening against a list of banned or undesirable materials and processes to a full life cycle analysis, with overheads of time and cost.

The concept of a circular economy has been used since the 1970s but the concept gained momentum with the design book "Cradle to Cradle: Remaking the Way We Make Things" by Braungart & McDonough (2002) that suggest to design things considering lifecycle development systems. In the report "Towards circular economy, economic and business rationale for an accelerated transition", the Ellen McArthur Foundation (2015) defined circular economy as "restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times." Considering the world of materials, circular economy can be associated to variety of lifecycle development approaches named for instance "reuse", "recycle", "recovery", "repurpose", "upcycle". The challenge is to understand the design impacts of these approaches despite the fact that these terms are often confused and thus misused.

Teaching "sustainable design" and "circular economy" as prospective trends in product design is the motivation of the educational workshop presented in this paper. This workshop is an opportunity for the students to analyze the complexity of user experience related to materials lifecycles. This paper aims at presenting the educational guidelines used to help students to perform value analysis of materials throughout subsequent use cycles in order to express different ways to regenerate value at all steps of product life cycle. These analyses intend to show the material's unexpressed potential in order to trigger creative thinking.

2 CONTEXT

In the last decade, reuse and upcycling gained more and more attention. In particular, since "reduce" and "reuse" were described as priority focus by European Union funding, some leading projects were unveiled in different countries. The headquarters of the European Council in Brussels wear a facade with hundreds of reclaim windows and leading car companies, like Peugeot, are producing concept cars with old newspaper inside (Peugeot Exalt and Peugeot Onyx). These projects enabled to redefine "reuse" strategies from local "Do It Yourself " strategies to global "circular economy" strategies.

The European Union (EU) Waste Framework Directive directive rWFD 2008/98/EC sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. In particular, the framework proposes a waste management hierarchy (Figure 1). As expected, "prevention" i.e. "non-waste" is the most favorable level. The second most favorable level is dedicated to strategies that enable the waste to become a product again i.e. "preparing for reuse". The less favorable level is "disposal". In this scheme, "recovery" is defined as less favorable than "recycling".

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Figure 1: Waste management hierarchy (rWFD)(2008/98/EC). European Commission.

Although "reuse" stands on a favorable level on the waste management hierarchy, it is obviously under-used in nowadays industrial economy where recycling is clearly more largely adopted. That might come from the fact that "reuse" strategies are not clearly defined and understood. Indeed, "reuse" covers a broad range of meanings and activities (Cooper & Gutowsky, 2015). In order to become a favorable solution in industrial strategies, "reuse" and "upcycling" need to be tested in case studies to be better understood in order to become transferrable from one type of industry to another. The most demonstrative case studies are found in the building and architecture industry e.g. in Paris with the Actlab project (Benoit, J. *et al.*) or in Brussels with the BBSM project (Ghyoot, 2017). The impact of "reuse" strategies in these industrial sectors are great in that building materials account for the greatest part of carbon emissions (Allwood *et al*., 2010a,b,c; Iacovidou & Purnell, 2016). Inspired by those case studies from building materials and based on the European directive rWFD 2008/98/EC, this paper intends to propose definitions for "reuse", "recycle" and "recovery" that could be further applied in an educational workshop proposed to the students that intends to analyze the value chain of materials used in the manufacturing industry (Ghyoot, 2018).

3 REUSE, RECYCLE... OR RECOVERY? FROM DEFINITION TO PROPOSITIONS

In the European directive rWFD 2008/98/EC, "recovery" means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. So finally, "recovery" is generic term that covers a broad panel of operations composed of: reuse, recycling and energy recovery. In the following, "reuse" and "recycling" are redefined.

In the European directive rWFD 2008/98/EC, "recycling" can be defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. Thus, "recycling" involves a complete loss of shape. "Recycling" can be clearly considered as a waste treatment and should not be associated to "reuse" strategies in that there are huge differences in material treatments in both strategies (Mutingi *et al*., 2016).

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In the European directive rWFD 2008/98/EC, “reuse” is described as « any operation by which products or components that are not waste are used again for the same purpose for which they were conceived ». In this definition, reuse is limited to life extension of the first use and does not require any change in shape and function. While this definition seems to be clear, in practice, items which are implemented in another use – with transformations and without transformations – are also called “reuse” (Ghyoot, 2018).

This is the main issue, which raise the following question: How should we call the strategy based on the use of a product or component that is not waste, but that is used in a different purpose for which it was designed? In this work, two words are proposed to differentiate those steps: “repurpose” and “refunction”. “Repurpose” is defined as a change of function but not shape, and “refunction” is defined as a change of function and shape in order to fulfil a new function without total shape loss.

In this section, five terms related to materials lifecycle has been (re)defined: Recycling, Recovery, Repurpose, Refunction, Reuse. These definitions have been used to build an axiology (i.e. a study of values) of materials lifecycle to be tested by students in course dedicated to sustainable design.

4 CASE STUDY. FROM PRODUCT TO DUST: AN AXIOLOGY OF MATERIALS LIFE CYCLE.

Twenty-seven students enrolled in a Master Degree in Engineering and Design participated in this case study proposed during a course of sustainable design in March 2018. Students were given the template shown in Figure 2 as a guideline to analyze the values embedded in the potential lifecycles of a material.

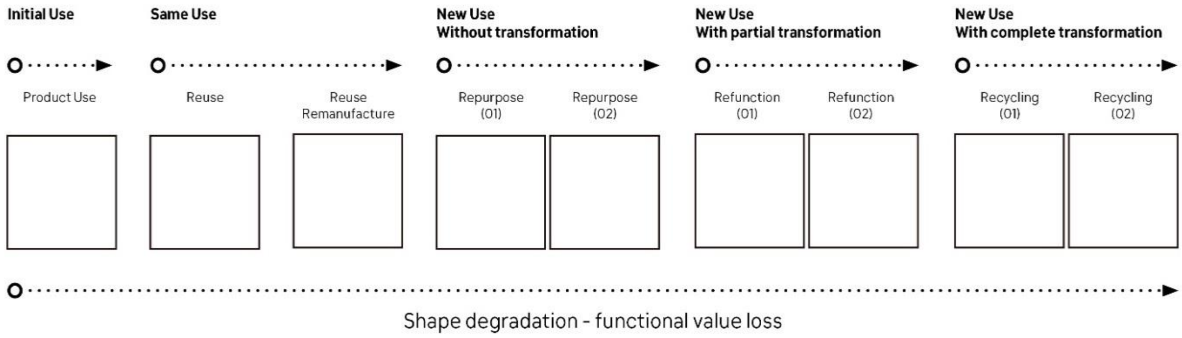

Figure 2: Template given to students as a guideline

4.1 Product selection and life cycle decomposition

With the template, the students were asked to choose a product. It was advised to prefer simple products as shown in the example (glass bottle) provided during the course (Figure 3). The original product had to be displayed in the first box. If the product contained several materials or components, each material or component should be analyzed in a different branch. For clarity purposes, in this paper, the analysis of a mono-material product (glass bottle) is presented.

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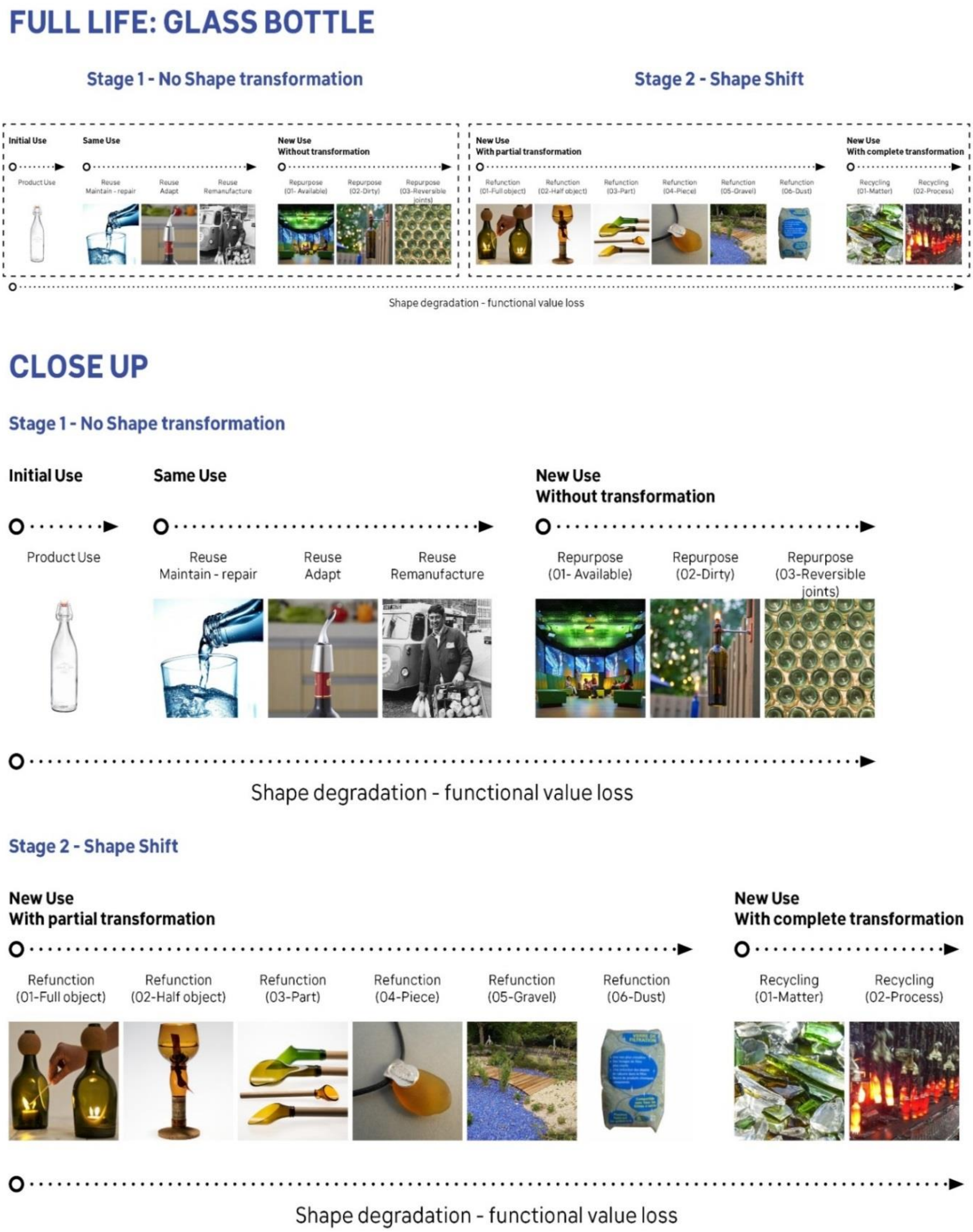

Figure 3: Value chain from glass bottle. Baptiste Menu.

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The upper dotted-line is split in different stages which depict various degrees of transformation and the appropriate vocabulary to describe it. Each step should be considered as a potential option to regenerate value. The lower dotted-line illustrate the shape degradation and function loss, going from the original shape to dust. Each transformation step is a shape generating process – morphogenetic process – which needs energy input (Ingold, 2017); the aim is to decrease as much as possible the energy needed between those steps. It starts from the original shape, then explore parts, pieces and finally the smaller scale possible: dust. Boxes have to be filled with a picture illustrating the concept, and students are asked to discuss their choices. They can add boxes or draw a new line if the chosen product requires a specific life cycle branch. In fact, in the case of complex products, components or multi-materials items need to be decomposed in separate branches in order to organize the materials flows (Figure 4).

Figure 4 is an example of an analysis performed by a student. Tires are multi-material products, which contains rubber, steel and textile fibers. At the end of life, materials are sorted through mechanical and magnetic processes in order to be recycled in different industrial sectors. Thereby, the dotted-line splits in three branches, one for each material.

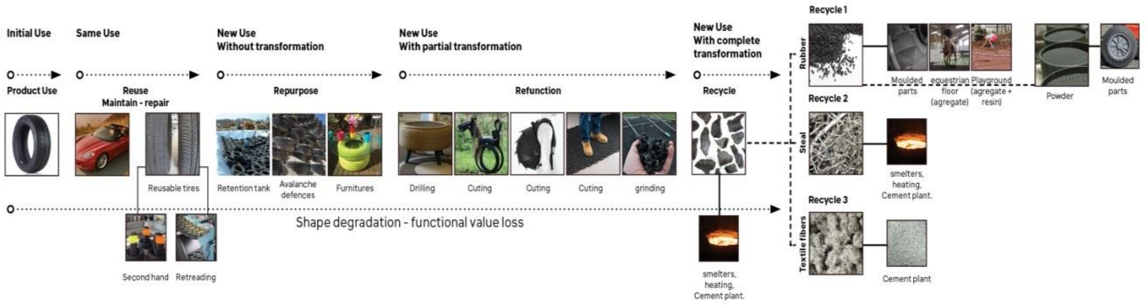

Figure 4: Value chain from tyres. Students: Joan Matas and Betty Corbineau.

Some steps could possibly overlap each other, or some choices could require some explanations. This is the reason why we ask the students to argue their choices. Each picture needs a reference and a sentence, which explain the reason of that selection. They need to describe the picture, explaining the new use phase or the process who lead to that step.

4.2 Product perspective: steps identification.

In that part, we will describe Figure 2 dedicated to the analysis of a glass bottle, which was the example provided during the design course. It aims to give an overview on a simple product life cycle: the case of a glass bottle. Two focus are done. On the one hand, stage one shows the life extension without shape transformation. This part is dedicated to multiple uses with no shape transformation. On the other hand, stage two describes the extended recovery potential before recycling. Both stages explore design ability to restore values – Economical, historical, symbolical, esthetical, usage, existence, etc. – through an innovative way to look at materials and know-hows which could possibly restore new functions (Riegl, 1903).

First the students focus their attention on the ways to repair and maintain the product in the initial use. This is the part dedicated to “prevention” and “reuse”. The idea is to explore the longest life possible in the original use. They think about manners to take care of the objects and try to identify channels and procedures to maintain it in an acceptable level of use. Then, they look for possible ways to resale, through second hand shops or Product Service System (PSS) strategies like remanufacturing. When this step is no longer possible, they start to explore another use without transformation, to preserve as much as possible the embedded energy. The object starts a new life cycle but serves three different purposes. The shape remains unchanged but use is renewed. First one is a reversible and easy access (Repurpose 01); Second one is a kind of repurpose that could possibly altered the object (repurpose 02); Third one is a repurpose that could broke the object (Repurpose 03). A bottle could be described as a part of a ceiling, or a « brick » for the walls. Little by little, the product will be altered by use and time. It will be fragmented in parts which possibly contain hidden functions.

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The neck of the bottle incorporate a funnel, a glass or a spoon, maybe another lamp foot, smaller that the first one… If we zoom in, each part of the product contains other product, semi-product, by product, and so on. At the end, when the shape is almost entirely lost, the functional potential is lower but still alive. Little glass stones are useful for jewelry or mosaic. It could be divided again in little gravels appropriate for aquarium, and swimming pool water filters. Finally, glass dust can be incorporate into cement in order to save sand resource. However, the choice of mixing materials without possibility to separate them will compromise the recycling step which needs pure matter to produce new qualitative secondary raw materials.

5 PEDAGOGICAL GOALS

This educational activity aims to make the student aware of the full value potential of product and materials until the recycling step, which involve a complete shape loss, or could possibly damage materials properties. Looking for the pictures stimulate student creativity and knowledge in materials and product conception. They handle the different concepts and learn vocabulary related to the transformation steps. All stages are explored from original use to complete transformation (Allwood *et al*., 2010a; Nilakantan & Nutt, 2015); in other words, from the step which needs low energy requirement (Use - Reuse) until the energy intensive metamorphosis (recycling).

The need to argue the choices is a good opportunity to be critical toward the sustainable design approach. Each step has to be compatible with the next one. The aim is to use knowledge that was explicated during classes to select the most relevant examples, in order to draw a consistent life cycle perspective. The research embody various design knowledge: Design for Maintenance, Design for Deconstruction (DfD), Design for disassembly (design for recycling and design for reuse), Component Based Design (CBD),

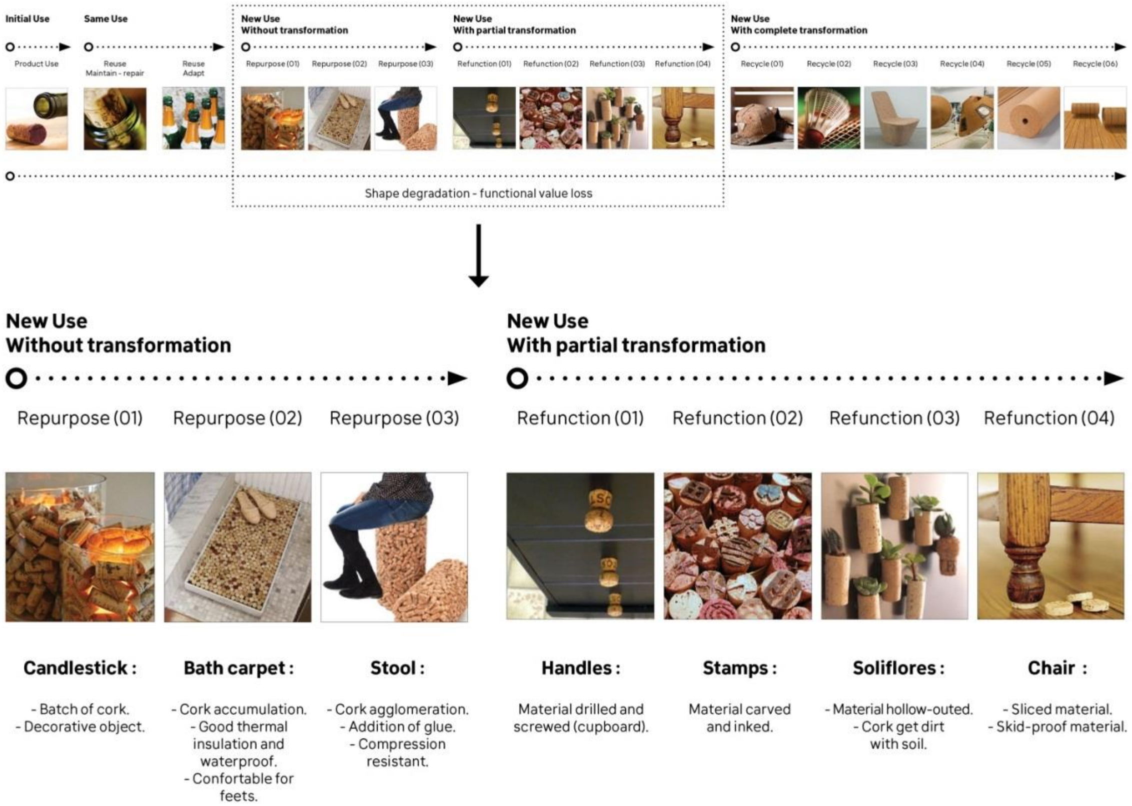

Figure 5: Close up on Repurpose and refunction. Value chain from cork. Students : Axel Cairon and Bérénice Bréchet.

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Design for adaptability, Design for Remanufacturing (DfRem), etc. Moreover, the students are encouraged to look carefully on the materials, fabrication processes and the way to identify reversible assemblies. The educational activity brings an overview on both traditional and alternative use. It pushes the boundaries beyond the conventional life cycle analysis, and brings some notions from both industrial and craft processes.

Fourteen objects have been analyzed by students. Some of them had difficulties to overcome the question and provided a very low level of details. The overall quality of the analysis is based on the life cycle consistency, which implies the ability of each step to be suitable with the next one. For instance using irreversible processes using concrete, glue, painting or mixing materials at early stages makes consequent steps in the lifecycle less compatible. Final part of the assessment is about student's ability to argue their choices in a clear and smart manner. For that, they provide a text document explaining each pictures, providing details on fabrication methods, materials and processes.

Figure 5 shows a students work with a focus on Repurpose and Refunction. Although they chose a product that use glue in the third repurpose (Repurpose 03) they described with care many possible use of cork, introducing captions under each selection. The examples selected by students are relevant, because they show a broad panel of transformations from craft to industrial processes. It covers daily life objects, like handles or stamps, until aerospace applications like heat shield.

6 CONCLUSION

Teaching "sustainable design" and "circular economy" as prospective trends in product design is the motivation of the educational activity proposed as an opportunity for the students to analyze the complexity of user experience related to materials lifecycles. As a result, the student's feedback were positive, the guidelines enabled to clarify the broad variety of concepts available to extend lifecycle of products. The better understanding of specific terms such as "reuse", recycle", "repurpose" related to value recovery helped them organize the existing solutions. It also helped them express unexplored ways to extend lifecycle of a given product and triggered creative thinking. This educational activity draw the attention of students on the wide range of possibilities embedded in materials: material properties and qualities at different stage of life cycles. Sustainable design becomes a tool to give a fresh look on waste management and material values.

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